

Development of Honda FCX

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Honda has been researching and developing fuel cells to resolve issues we face such as air pollution and energy conservation. In September 1999, Honda installed its internally developed fuel cell stacks on its fuel cell test vehicle for the first time. Since then, we have made efforts to increase the commercial value of our fuel cell vehicles by setting the aim of our fuel cell development to attain a more compact design with higher output, and to be more adaptable to wider areas. In October 2003, Honda announced the new-generation fuel cell stack, and delivered the Honda FCX to New York State in November 2004. We test-ran the FCX in wider areas and a great deal of information was obtained regarding the FCX's environmental adaptability and durability.

This paper describes the current and future work on the Honda FCX fuel cell vehicle and fuel cell stack.

Keywords: Fuel Cell, Fuel Cell System, Fuel Cell Vehicles, Fuel Cell Durability

1. INTRODUCTION

In response to environmental issues such as air pollution, global warming, and the drain of fossil fuels, Honda is doing our best to reduce exhaust-gas emissions through its eco-friendly development of natural gas-fueled vehicles, the electric car, and a hybrid vehicle. Only fuel cell technology can solve all these issues, and the next generation type fuel cell vehicle "FCX" (Figure 1) technical development and the cost cut which start the basic research of a fuel cell, use hydrogen as fuel, and has been running from the 1980s for the spread of fuel-cell vehicles are tackled in Honda. During the original development of a fuel cell, the fuel reforming system was examined. Now, Honda has focused its development activities on the fuel cell vehicle, which uses high pressure hydrogen gas, to achieve the cleanest exhaust emissions. And a fuel cell vehicle that is more responsive to environmental issues has been delivered to the market. These arrangements have increased the number of miles that FCX vehicles have been driven on public roads, and daily use of the vehicles has enabled a significant amount of information on the vehicles to be obtained. The FCX vehicles are being used under a variety of climatic, traffic and road conditions, a situation that is well suited to verifying the durability of the vehicles and their suitability to various environments. This paper describes the durability of the FCX fuel cell stack.

2. THE CHARACTERISTIC OF THE HONDA FUEL CELL

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2.1 Fuel Cell Stack

Conventional fuel cell stacks have employed fluorine electrolyte membranes and carbon separators, although these features had negative effects on achieving high performance. Honda's stack implements aromatic electrolytic membranes, which have high proton conductivity and stamped metal separators formed with unitized seals, both of which are characterized by their springiness. As a result, output density has increased twofold. Figure 2 shows the technological evolution in terms of the compactness and stack weight (power density), respectively.

2.2 Aromatic Electrolyte Membrane

We have developed an electrolyte membrane with a new molecular structure. This membrane consists of a main chain of an aromatic structure and concentrated ion exchange substrates (sulfone substrates). Densely distributed ion exchange substrates show high ion conductivity, reducing membrane resistance by 1/2 even below the freezing point. This enables the fuel cell stack to generate electricity at -20 degrees centigrade. In addition, it features lower gas permeability compared to the conventional fluorine electrolyte membrane (Figure 3)

The aromatic structure features high thermal stability and durability, operable at temperatures as high as 95 degrees centigrade. Figure 4 shows high temperature durability of the aromatic electrolyte membrane. This membrane overcomes the problem of the fluorine electrolyte membrane, which becomes soft and eventually deforms at high temperatures.

2.3 Stamped Metal Separator with Unitized Seal



Figure 1: 2005 model FCX

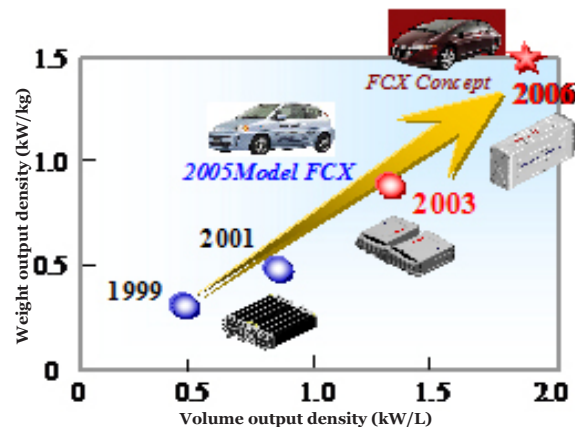


Figure 2: Honda fuel cell stack evolution

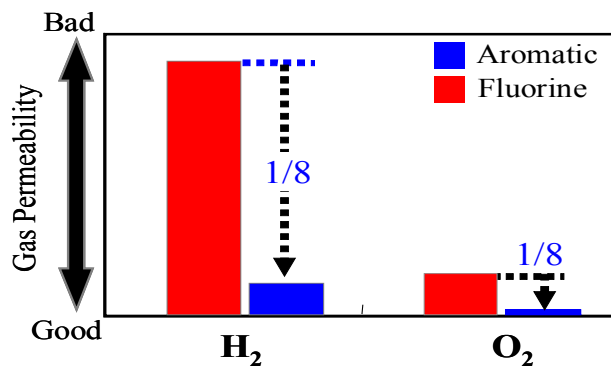


Figure 3: Gas permeability (80°C)

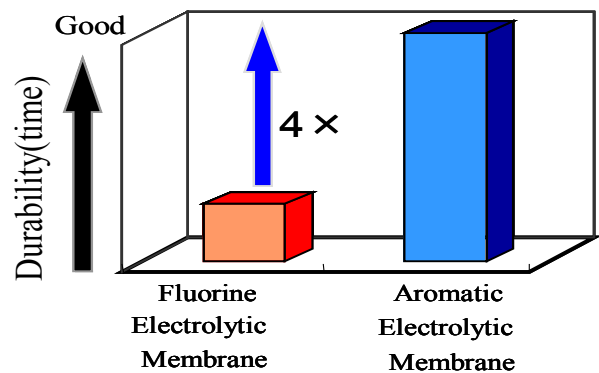


Figure 4: High temperature durability

Stainless steel is chosen to satisfy electric conductivity and heat conductance and, furthermore, is stronger than carbon, so the thickness of the separators can be thinned to half. Hence, thermal conductivity has increased five-fold by adopting stainless steel separators (Figure 5). As a result, stacks can be heated quickly, and the time needed to start the FC system is reduced. However, there are issues that occur in relation to the metallic material, oxidation and corrosion, due to the passage of current. When we use a passive treatment to guard the metal surface from oxidation and corrosion, the resistance of the metallic surface increases. By this process, the stainless steel base is protected from oxidation and corrosion, and enhanced electrical and thermal conductivity are given. Figure 6 shows the microscopic surface of the metal separator and the cross section model of the separator.

3. 2005 MODEL FCX OPERATION HISTORY

The FCX vehicles that have been delivered to date are all being put to daily use. Individual customers vehicle have also put in the most kilometers, totaling approximately 24,000. These vehicles are being used under a variety of conditions and for a variety of purposes, including commuting and parking enforcement. Figure 7 shows characteristic usage patterns. FCX vehicles

have also been used for two years by government agencies in Japan for a variety of purposes, including their utilization as a state car and providing test drives at events in the nation's regions. Corporate users are also using the vehicles for test drives in regional areas and for business trips.

4. ISSUES ARISING FROM PRACTICAL USE OF THE SYSTEM

Customer use of the vehicle in the U.S. and Japan clarified a number of issues. With regard to the durability of the FC stacks in particular, a great deal of information was obtained regarding start and stop deterioration, in addition to the cycle deterioration that was already known. Table 1 shows the factors causing deterioration and the type of countermeasures being applied.

As indicated above, the use of an aromatic electrolyte membrane has resulted in superior durability at high temperatures. This is extremely effective with regard to cycle deterioration, given the high degree of change in load in the cycle, enabling the achievement of a high level of cycle durability. However, customer usage of the vehicle indicated that the level of deterioration was higher in actual use than in a simple cycle durability

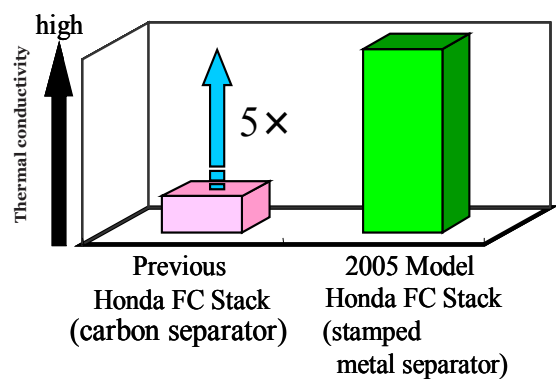


Figure 5: Comparison of thermal conductivity

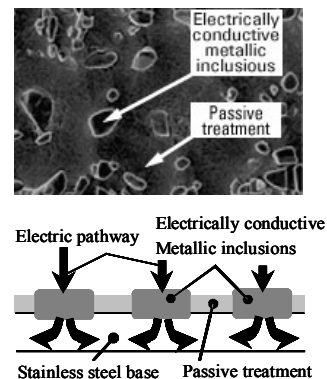


Figure 6: Surface image and cross section model of separator

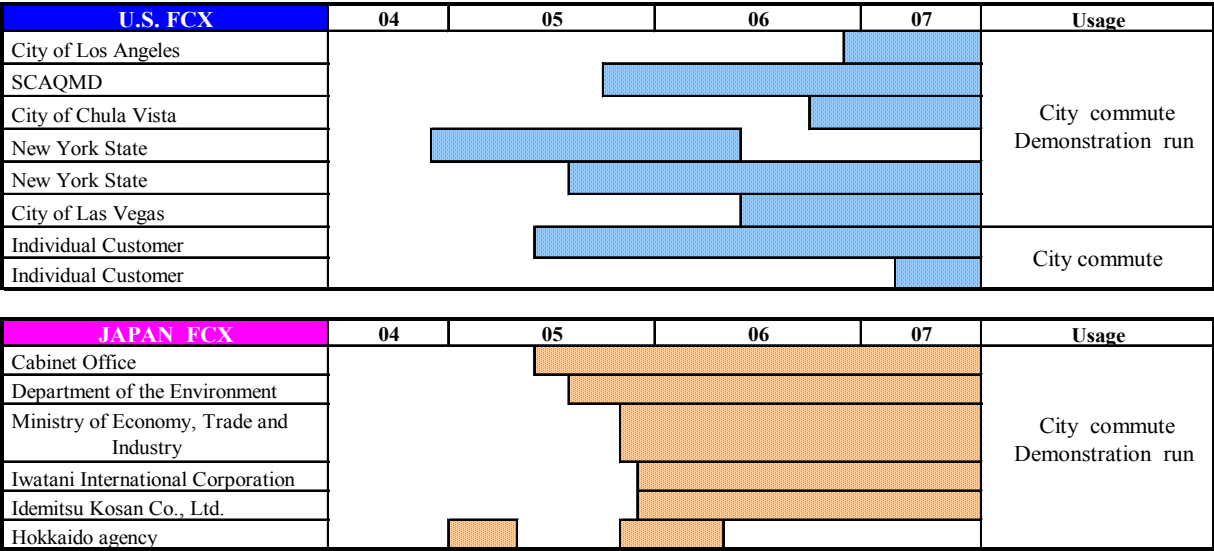


Figure 7: 2005 model FCX operation term

Classification	Deterioration factors	Type of countermeasures
Cycle deterioration	➢Generation water and humidification water management (Prevention of the flooding) ➢Influence on vehicle usage (Starvation at immediate acceleration)	●Improvement of Membrane / MEA toughness ●Equalization of the generation distribution Reflected in test cycle mode
Start and stop deterioration	➢Influence of the residual hydrogen (Formation of partial battery) ➢High electric potential	●Improvement of Membrane / MEA toughness ●Hydrogen supply control Reflection to the test cycle mode

Table 1: Deterioration factors and the type of countermeasures

test. Figure 8 shows a comparison of the results of a cycle test and deterioration resulting from customer use. As indicated in Table 1, a variety of factors are thought to cause deterioration during customer use of the vehicle. The process of stopping and restarting the system is one of these factors. Figure 9 shows a

comparison of the results of a cycle test that included the process of stopping and starting the system and deterioration during customer use.

The results clearly indicate that the level of deterioration of output increases when the process of stopping and starting the system is included in the cycle durability test. The inclusion of the new factor has enabled the test to reproduce conditions of performance deterioration close to those resulting from customer use, but it will be essential to consider the inclusion of further factors in order to achieve more accurate reproduction of deterioration during customer vehicle use.

The deterioration caused by stopping and starting the system is closely related to the gas condition inside the FC system stack, in particular inside the fuel cells. Figure 10 shows an image of the gas condition inside the fuel cell from system shutdown to restart. Normally,

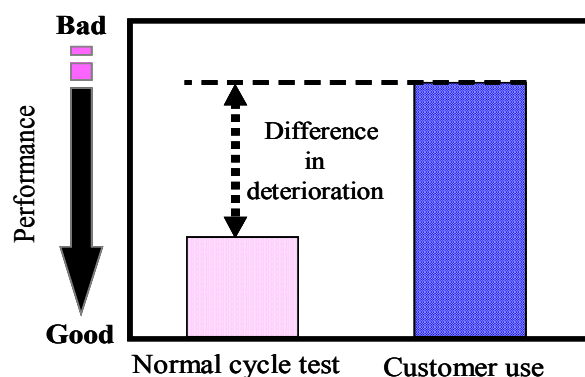


Figure 8: Difference of deterioration, normal cycle test and customer use

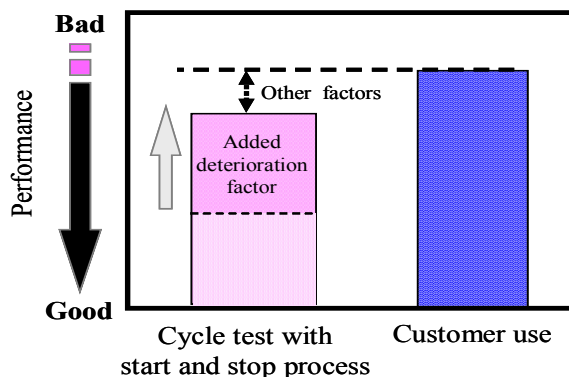


Figure 9: Difference of deterioration, modified cycle test and customer use

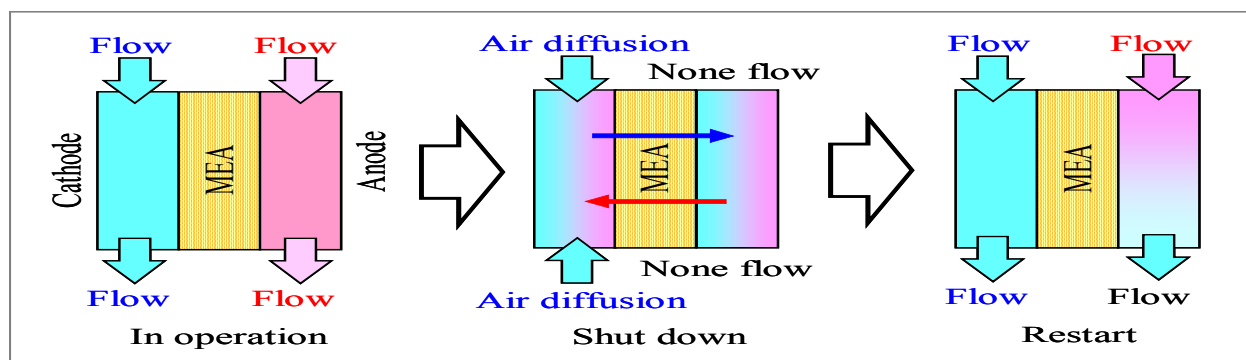


Figure 10: Mixture image of gas phase in the cell

when the system is stopped, there is a hydrogen condition at the anode electrode and an air condition at the cathode electrode. However, after a certain amount of time elapses, consumption of a gas mixture caused by crossover through the electrolyte membrane and air diffusion from the inlet and outlet of the cathode results in the formation of an condition consisting largely of air at both electrodes. When the system is restarted in this state, hydrogen and air mix in the anode. This forms a partial battery, resulting in a localized state of high electric potential. This high electric potential causes the Pt that forms the electrode catalyst to dissolve and corrodes the carbon in the substrate and the gas diffusion layer. This causes a decline in reactivity and gas diffusion, resulting in reduced output. These issues demand increased resistance to electric potential in the materials employed in the fuel cells and further examination of system control. Ongoing research is being conducted to resolve these issues.

5. CONCLUSIONS

FCX vehicles using Honda FC stacks employing aromatic electrolyte membranes displaying excellent gas isolation performance and thin stainless steel separators have been put into practical use since 2004. This practical use has indicated the following:

- o We specified the process of stopping and starting the FC system as one of the deterioration factors in the field. We tried a cycle test that included this process. As a result, the deterioration of the stack performance is accelerating. Therefore, we were able to prepare the basic test mode which could reproduce the durability and reliability of the customer usage.

- o The process of stopping and starting the FC system occurs a high electric potential condition in an electrode, resulting in corrosion of the electrode catalysts and gas diffusion layers.

- o We achieved the direction of the improvement by reproducing the deterioration factor of the customer usage. We are going to apply this knowledge for new materials, a stack design, and the system control.

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